

ATTACHMENT 8 – BENEFIT AND COST ANALYSIS

The benefit-cost analysis is separated into two separate sections: 1) Big Dry Creek Dam and 2) Stormwater Management Basins. This was done because the economic analysis is different for these two components of the project. A benefit-cost ratio is provided for each of these two components. However, an overall benefit-cost ratio is also provided since the two components are considered a single integrated project that provides the same benefit (i.e. reduced flood damage and increase floodwater storage) for the Fresno-Clovis Metropolitan Area.

BIG DRY CREEK DAM TOE DRAIN MODIFICATION

Project Costs

The estimated cost for the toe drain modification at Big Dry Creek Dam is \$2.97 million. This includes costs for engineering, permitting, construction and construction management. A copy of a detailed cost estimate is provided in Appendix 8-1.

Operation and Maintenance Costs

Operation and maintenance costs for the new toe drain will include pumping costs and periodic seepage reports. Pumping the collected water is estimated to cost \$3,300/year which is based on \$2,200 electrical costs for pumping 180 AF/year, \$200 for staff salaries for monitoring, and \$900 for general pump maintenance. FMFCD will hire a qualified geotechnical engineer to prepare a Seepage Analysis Report when sand boils or other signs of heavy seepage appear. This is assumed to occur at most once every five years at a cost of \$8,500/report. Other tasks, including regular inspections, will be performed by FMFCD staff as part of their regular duties when they periodically visit the dam.

Replacement Costs

The project will include a pump station and six monitoring wells. These will likely require replacement after 25 years, so replacement costs of \$417,000 will be incurred in year 25. The toe drain piping is estimated to have a life expectancy of 50 years.

Present Value

The total value of the costs over a 50-year life cycle is shown on DWR Economic Table 16a (Appendix 8-2). The project has a total present value of \$3.1 million.

Identification of Flood Events

Description of Dam

The Big Dry Creek Dam is a homogenous earth-fill dam that is 25,300 feet long and has a maximum height of 45 feet. The dam has a storage capacity of 30,200 AF at its spillway crest.

Dam Break Analysis

In 1995, the US Army Corps of Engineers (USACE) performed a dam break analysis for Big Dry Creek Dam. The results are presented in a report entitled “*Dam Breach Analysis for Big Dry Creek Dam*” (see Appendix 3-2). The discussions below are based on the data presented in the dam break report.

The dam was assumed to fail by piping. The breach was assumed to be 80 feet wide at the dam invert. The modeled dam breach produced a hydrograph with a peak flow of 69,900 ft³/sec occurring one hour after the breach began to form. The Muskingum-Cunge Routing Method was used to route the hydrograph from the dam downstream through the Fresno-Clovis Metropolitan Area.

Most breaches occur after flow begins to overtop the dam, however, for the purposes of the USACE study, they simulated a dam breach occurring with the water surface at the spillway crest (from a piping failure), and after inflow to the reservoir has essentially ended. This is often called a ‘sunny day failure’. Such conditions simulate a dam breach with the greatest element of surprise and no time for evacuations, warnings, etc. prior to the breach.

Inundation Map

Figure 8.1 is a map showing the potential inundation from a failure at Big Dry Creek Dam. The map is based on inundation boundaries prepared by the USACE (1995). The map shows the inundation at different time intervals over a 14 hour period. The inundation will cover 60.7 square miles and flood a large portion of the Cities of Fresno and Clovis, and unincorporated areas of Fresno County.

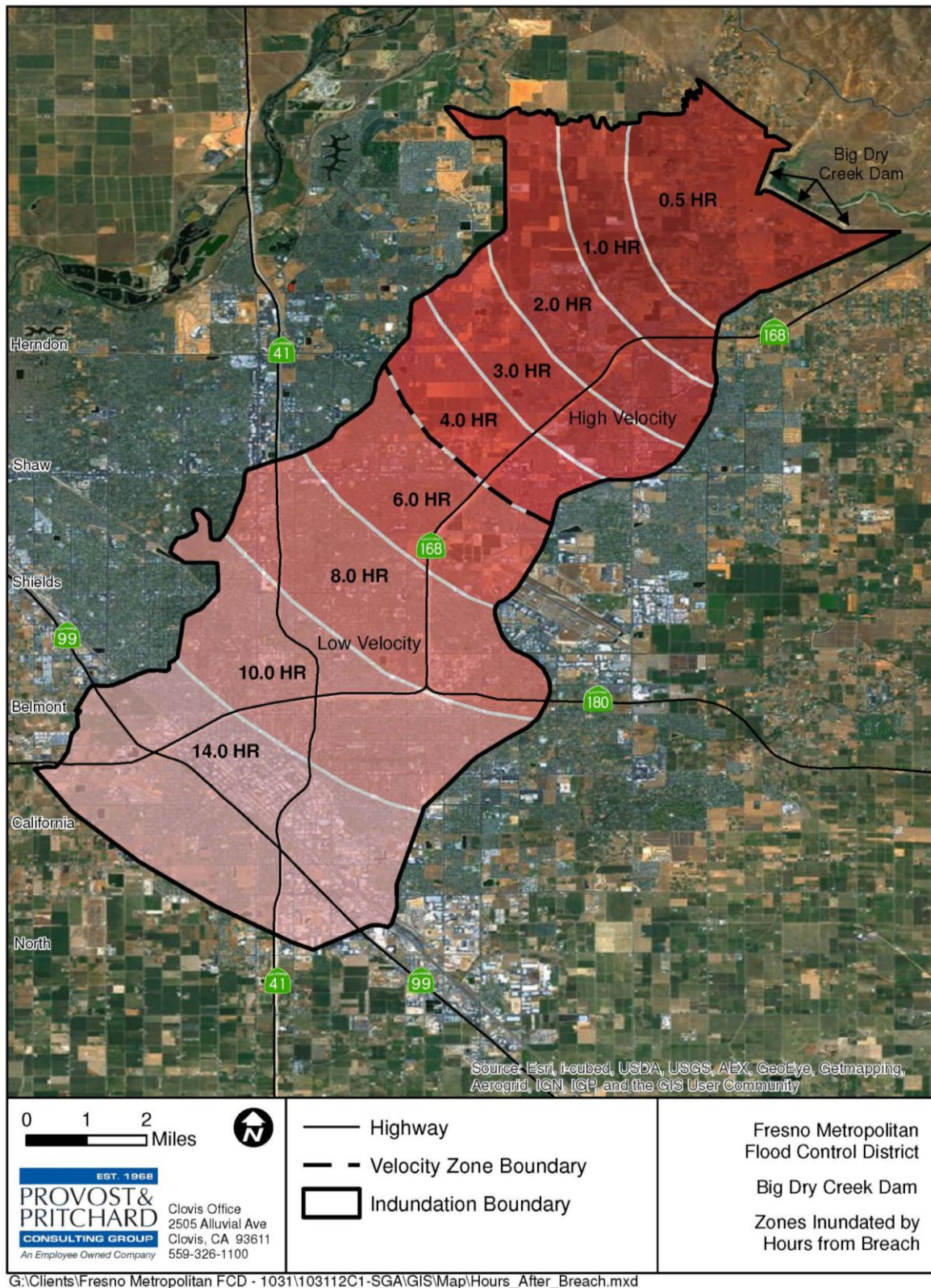


Figure 8.1 – Dam Failure Inundation Map

Flow Velocities and Depths

Modeled flow velocities ranged from nearly 40 ft/s in the first ½ mile below the dam, to wide shallow flow of approximately 0.6 ft/s below Highway 99 in Fresno. **Table 8.1** shows flowrates and velocities at various locations in the inundated area.

Table 8.1 - Approximate Travel Time of Flows from Dam to Selected Locations

No.	Location	Distance to Dam (mi)	Max Flow (cfs)	Arrival Time**(hrs)	Max Vel. (cfs)
1	Intersection of Sunnyside Ave and Nees Ave	2.4	67,000	0.5	13**
2	Intersection of Peach Ave and Herndon Ave	4.0	62,000	2	2
3	Intersection of Bullard Ave (6 th) and Clovis Ave, Clovis	4.1	62,000	2	2
4	Intersection of Millbrook Ave and Ashlan Ave, Fresno	7.9	55,000	6	1
5	Intersection of Clinton Ave and 1 st St., Fresno	9.3	49,000	8	1
6	Intersection of McKenzie Ave and Blackstone Ave, Fresno	11.3	47,000	10	1
* Travel time of hydrograph peak from dam to indicated location. Travel time estimates rounded to nearest ½ hour					
** Flow rate exceeds 35 ft/s in upper reaches					

Source: USACE, *Dam Breach Analysis for Big Dry Creek Dam, California, 1995*

Modeled flood depths are generally 3 feet or less. Most areas will experience flooding of less than 2 feet in depth. Isolated low lying areas near channels may experience flooding of up to 6 feet in depth. Care should be taken in using the inundation map to determine precise flood depths, as the map presents a composite overflow from multiple breach scenarios. However, based on this data, it is assumed that flooding averages between 1 and 2 feet throughout the inundation area.

Flow velocities are generally 2 feet per second or less beyond 4 miles from the dam. Very dangerous conditions will exist within 4 miles of the dam. Consequently, the inundation map showed two zones: High Velocity Zone (less than 4 miles from dam) and the Low Velocity Zone (more than 4 miles from dam).

Delineated flood limits represent the best estimate of expected flooding. Additional areas of shallow sheet flooding (1 ft or less in depth) may occur along canals and streets outside of the delineated flood zones. Flooding outside the delineated zone (other than that within canals) is shallow flow with low velocity.

History of Seepage

The presence of seepage and sand boils at the dam created the impetus for installing a new toe drain. Small boils were observed in January 1997 with a maximum pool elevation of 422.5. The

occurrence of small diameter (1/4 to 1-inch) sand boils was again observed during the April 2006 storm event at a maximum pool elevation of 419.6 feet over a 6-day period. Small diameter sand boils were also observed during the flood events of December 2010 to February 2011 at a maximum pool elevation of 419.02 feet.

Geotechnical Analysis

In January 2013, BSK Associates of Fresno, California evaluated the probability of a dam failure with and without the proposed toe drain (see Appendix 7-2). Two scenarios were evaluated:

- Short Term Flood Storage (1-day) = 30,300 AF at elevation 432.7 feet
- Long-term Steady State Flood Storage (10 days) = 27,500 AF at elevation 431.5 feet

BSK provided the following probabilities of failure based on subjective judgment of available data.

Table 8.2 – Probability of Big Dry Creek Dam Failure

Toe Drain Modification	1-Day Flood Storage Duration (El. 432.7 ft)	10-Day Flood Storage Duration (El. 431.5 ft)
None	75%	65%
Toe Drain Modification	Near zero	Near zero

Both of these scenarios represent a 230-year event, but the 1-day event has a slightly higher risk of failure and was therefore used in the analysis.

Boils appeared at the dam at a water elevation of about 420 feet. The water was clear indicating that minimal erosion was occurring within the dam. The water was left at this level for 6 days. The dam appeared stable at this water level, but FMFCD did not allow water levels to rise due to concerns from FMFCD staff and their geotechnical consultant that the boils would increase and lead to piping and eventually an embankment failure. Based on these observations, it is assumed that the risk of failure begins at elevations greater than 420 feet with an inundation period of 7 days or more. Appendix 8-3 includes a reservoir stage frequency curve for Big Dry Creek Dam (USACE, 1986). The graph shows that a water level at 420 feet for 7 days is approximately a 45-year event.

The following probabilities were used in the flood damage assessment based on observations at the dam in 2006 and 2011, and the risk analysis provided by BSK Associates.

Table 8.3 - Big Dry Creek Dam Failure Probabilities

Description	Scenario 1	Scenario 2
Water Surface Elevation	420 feet	432.7 feet
Event Frequency	45-year	230-year
Storage Duration	7-Day	1-Day
Without Toe Drain Modification	0%	75%
With Toe Drain Modification	0%	Near 0%

Historical Flood Damage

No historical flood damage has occurred from seepage or a failure of Big Dry Creek Dam. However, some local flooding has occurred from short duration, high intensity rainfall. The damage from these events was used to identify typical damage to local structures from shallow flooding. National data on typical flood damage costs was also collected. Below is a summary of historical flood damage costs in FMFCD, and typical flood damage costs provided by the Federal Emergency Management Agency (FEMA).

Fresno Metropolitan Flood Control District

FMFCD experiences periodic flooding that damages residential structure. The flooding typically occurs when high intensity rainfall overwhelms the flood control system. The estimated damages from these events are summarized in Table 8.4. The depth of water during each event is not precisely known, but the flooding was shallow and estimated to be one foot or less.

Table 8.4 - Historical Flood Damage to Residential Structures in Fresno-Clovis Area from Stormwater Basin Overflow

Flood Event	Year	Estimated Claims	Inflation Index (2012)
1	1993	\$9,481	\$15,064
2	1993	\$23,000	\$36,000
3	1993	\$9,878	\$15,695
4	1993	\$11,826	\$18,790
5	1993	\$6,276	\$9,972
6	1993	\$16,800	\$26,693
7	2006	\$164,076	\$186,859
8	2007	\$119,995	\$132,873
9	2005	\$180,302	\$211,962
10	2007	\$134,996	\$149,484
Avg. Basin Overflow Claim - \$80,339			

Notes:

1. Property damage excludes any cost for temporary housing, lost employment or emotional distress that is subjective to the claimant. Monetary values listed are limited to the property, structure and contents.
2. Inflation per Consumer Price Index Inflation Calculator – Bureau of Labor Statistics, United States Department of Labor (http://www.bls.gov/data/inflation_calculator.htm)

Federal Emergency Management Agency

The Federal Emergency Management Agency provides an on-line flood damage assessment tool for estimating repair and replacement costs at residential homes¹. The tool was developed for the National Flood Insurance Program. Table 8.5 lists estimated damages for varying depths at a 2,000 square foot home, which is representative of a typical home in the Fresno-Clovis area.

Table 8.5 – Average Costs to Repair Flood Damage (2,000 square foot home)

Depth of Flooding	Estimated Damage
1-inch	\$20,920
6 inches	\$39,150
1-foot	\$52,220
2-feet	\$62,880

The same numbers were also reported by the Insurance Information Institute according to a January 2013 article on CNNMONEY.com entitled “*Lessons from Sandy*” (see Appendix 8-4).

¹ http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/the_cost_of_flooding.jsp

The national data provides lower average damages costs than local data collected by FMFCD. The national data was used in the economic analysis to provide a conservative estimate of damage costs. Based on the national data provided above, the following damage values will be used for impacted structures.

Residential Homes. Residential homes are assumed to have average damages of \$21,000. This represents a flood depth of 1-inch, according to Table 8.5. This is a conservative value since flood depths will likely be 1 to 2 feet, according to the USACE.

Apartments and Condominiums. Individual apartment and condominium units would have less damage than residential homes because they are typically smaller, some are located on upper stories, and they may contain less valuable items. As a result, the estimated damage to each unit was conservatively assumed to be a nominal \$2,000.

Commercial/Industrial Buildings. No specific data was found for estimating damage to commercial and industrial buildings. However, commercial and industrial buildings are commonly larger than residential homes, and may contain valuable merchandise or equipment. Therefore, the typical damage at commercial and industrial structures would typically be higher than at residential homes. Damages were assumed to be \$39,000/structure, which is based on a flooding depth of 6-inches and a 2,000 square foot structure. This value represents repair/replacement costs and does not account for lost revenue during flooding or cleanup.

Critical Facilities. Critical facilities such as ambulance headquarters (dispatch centers), hospitals, fire stations, etc. are typically larger than residential homes and may have valuable equipment. The damage at critical facilities was also assumed to be \$39,000/structure.

Dam Reconstruction. The breached section of the dam will require reconstruction. USACE (1995) assumed that the breach would be 80 feet wide. The estimated cost to reconstruct the breached portion of the dam is \$2.25 million (see Appendix 8-5 for cost estimate).

Flood Damage Reduction Benefit Analysis

With Project Conditions

With the new toe drain, the risk of a dam failure was determined to be 'near zero' by BSK Associates in a letter dated January 9, 2013 (Appendix 7-2).

Without Project

Without the project there could be flooding during a large storm event that causes the following types of damage:

1. Shallow flooding of residential, commercial and industrial buildings would damage carpets, floors, basements, baseboards, lower parts of walls and furniture, merchandise, equipment, and other items stored on the ground or low to the ground.

2. The flood control benefits of the dam will be temporarily lost until the dam is repaired, making subsequent smaller storms more dangerous.
3. Impacts to wildlife living in urban areas.
4. Damage to agricultural crops.
5. Damage to infrastructure such as roads, bridges, railroads and utility lines.
6. Erosion and sedimentation.

Ideally, a survey of all properties should be attempted to determine an accurate count of structures and values. However, this is not possible nor economically justified for such a large area. Therefore, estimates from secondary data remains the preferred method. This approach is also recommended by USBR (2000). Data on existing structures was obtained from land use data provided by Fresno County, and the United States Geologic Survey National Map for 2013.

Avoided physical damage

Physical damage will primarily occur to residential homes, apartments, condominiums, commercial/industrial buildings, and critical facilities (police, fire, hospitals, schools, etc.).

Residential Homes. As shown in Figure 8.1, the inundation area has significant urban development. A summary of residential homes impacted is provided in Table 8.6.

Table 8.6 – Residential Homes Impacted

Description	No. of Residential Homes
High Velocity Zone	18,996
Low Velocity Zone	38,568
Total	57,564

Apartments and Condominiums. A summary of apartment and condominium units potentially impacted is provided in Table 8.7.

Table 8.7 – Apartments and Condominiums in Inundation Area

Description	No. of Apartment and Condominium Units
High Velocity Zone	7,247
Low Velocity Zone	25,047
Total	32,294

Commercial and Industrial Buildings

A wide variety of commercial and industrial buildings are found in the inundation area, as shown on Table 8.8.

Table 8.8 – Commercial and Industrial Buildings in Inundation Area

Description	High Velocity Zone	Low Velocity Zone	Total
Auto Service Center/New Car Sales	10	8	18
Bank (Financial Institution)	19	27	46
Car Wash	8	20	28
Cell Tower Sites	0	2	2
Church	49	210	259
Cold Storage & Slaughter House	0	19	19
Commercial Store(s)	561	1,967	2,528
Cotton Gin & Compress	0	1	1
Factory	0	11	11
Fraternal Lodge	6	30	36
Fraternity (Social) House	1	27	28
Freight Truck Terminal	0	12	12
Funeral Home	2	15	17
Garage	49	394	443
General Office	326	1,759	2,085
Hospital	1	4	5
Light Industrial	20	91	111
Medical-Dental Office	120	471	591
Mini Storage	8	13	21
Motel	7	52	59
Nursery (Plants)	3	0	3
Packing House	20	9	29
Parking/Sales Lot (Used Cars)	41	332	373
Restaurant	58	219	277
Service Station	5	29	34
Shopping Center (Community)	4	0	4
Shopping Center (Mini)	0	3	3
Shopping Center (Neighborhood)	12	11	23
Shopping Center (Regional)	1	3	4
Small Food Store	13	68	81
Super Market	5	9	14
Theater	1	7	8
Warehouse	109	705	814
Water Company	0	5	5
TOTAL	1,459	6,533	7,992

Critical Facilities

Table 8.9 summarizes critical facilities that would be impacted.

Table 8.9 – Critical and Important Facilities Impacted by Flooding

Description	High Velocity Zone	Low Velocity Zone	Total
Ambulance Headquarters	0	2	2
Hospital	0	2	2
Law Enforcement	1	8	9
Fire Station	4	8	12
School/Daycare	27	95	122
College/University	2	4	6
Total	34	119	153

If critical facilities are flooded, ambulance headquarters, fire stations and hospitals may have reduced abilities to respond to flood-related emergencies. A large number of schools are impacted, which could result in a loss of school days. The locations of the critical facilities are shown on **Figure 8.2**.

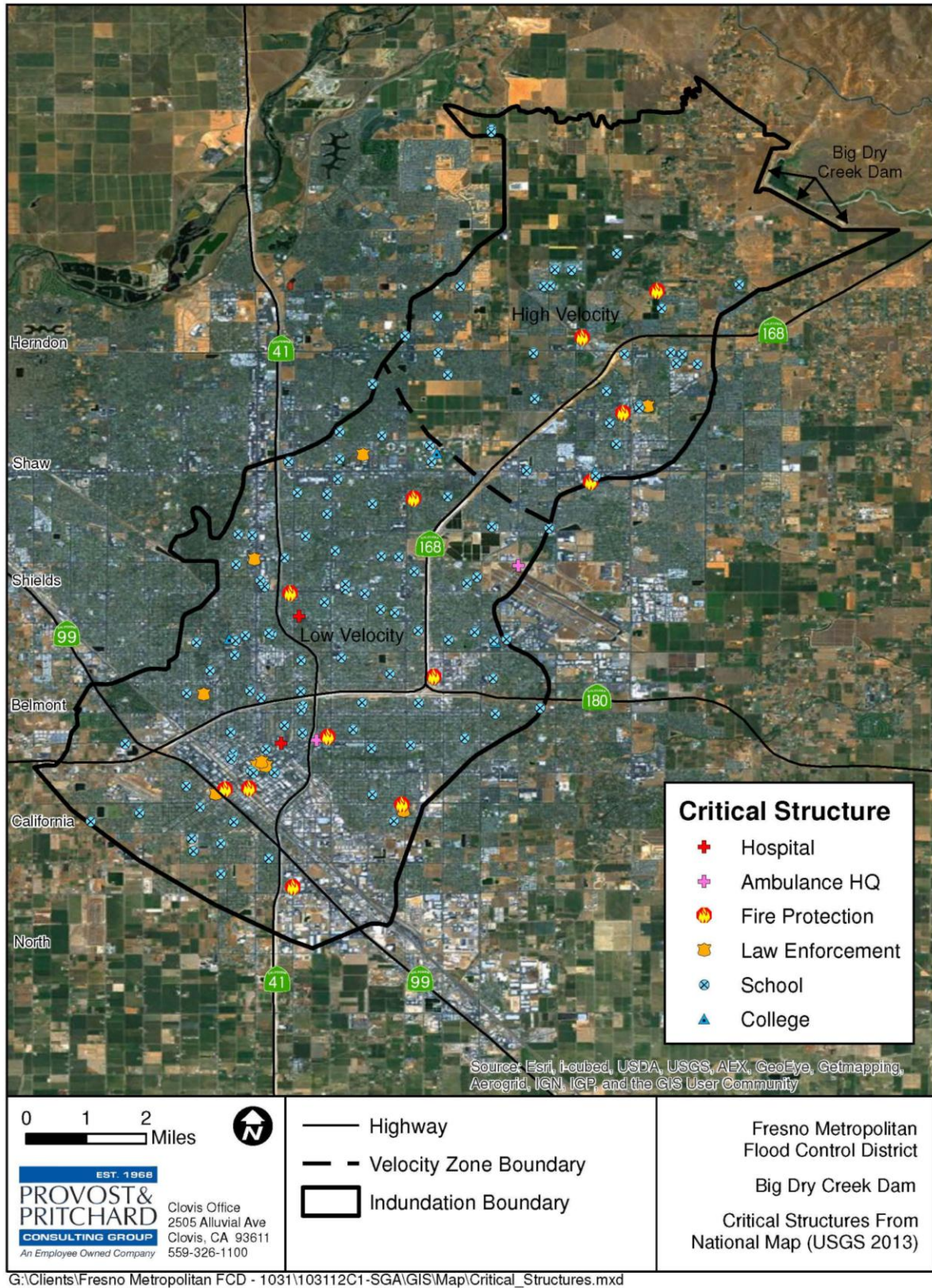


Figure 8.2 – Critical Structures Impacted

Flood Response and Intervention

Some residents in the Low Velocity portion of the inundated area may have time to intervene and reduce flood damage. Floodwater will not reach this area until 4 to 14 hours after the dam breach. Responses could include sandbagging, mobilizing pumps, evacuation, and relocating items. To account for this, the economic analysis only considers damages to the High Velocity Zone. This is very conservative since the majority of residences in the Low Velocity area would probably not have the time, opportunity, or equipment to reduce flood damage.

Total Flood Damage

A summary of total flood damage from a dam failure in the High-Velocity Zone is provided in Table 8.10.

Table 8.10 – Total Flood Damages to Structures from Dam Failure (230-year storm)

Description	Number in Inundation Zone	Damage / Structure	Total Damage
Single Family Residential Homes	18,996	\$21,000	\$398,916,000
Apartments and Condominiums	7,247	\$2,000	\$14,494,000
Commercial and Industrial Buildings	1,459	\$39,000	\$56,901,000
Critical Facilities	34	\$39,000	\$1,326,000
Big Dry Creek Dam Repairs	1	\$1,800,000	\$1,800,000
		Total	\$473,437,000

Area

The total area flooded in the high and low velocity zones is summarized in **Table 8.11**.

Table 8.11 – Area Impacted

Zone	Area		Remarks
	acres	square miles	
High Velocity	16,100	25.1	Flow velocity > 2 ft/sec
Low Velocity	22,800	35.7	Flow velocity < 2 ft/sec
Total	38,900	60.8	

Population Impacted

The population residing in the inundated area was estimated to be 255,855 using 2010 US Census Data. The estimate is based on census blocks that are completely enclosed by the inundation area, and ignores blocks that are partially inundated. **Figure 8.3** shows the census population density in the inundated area.

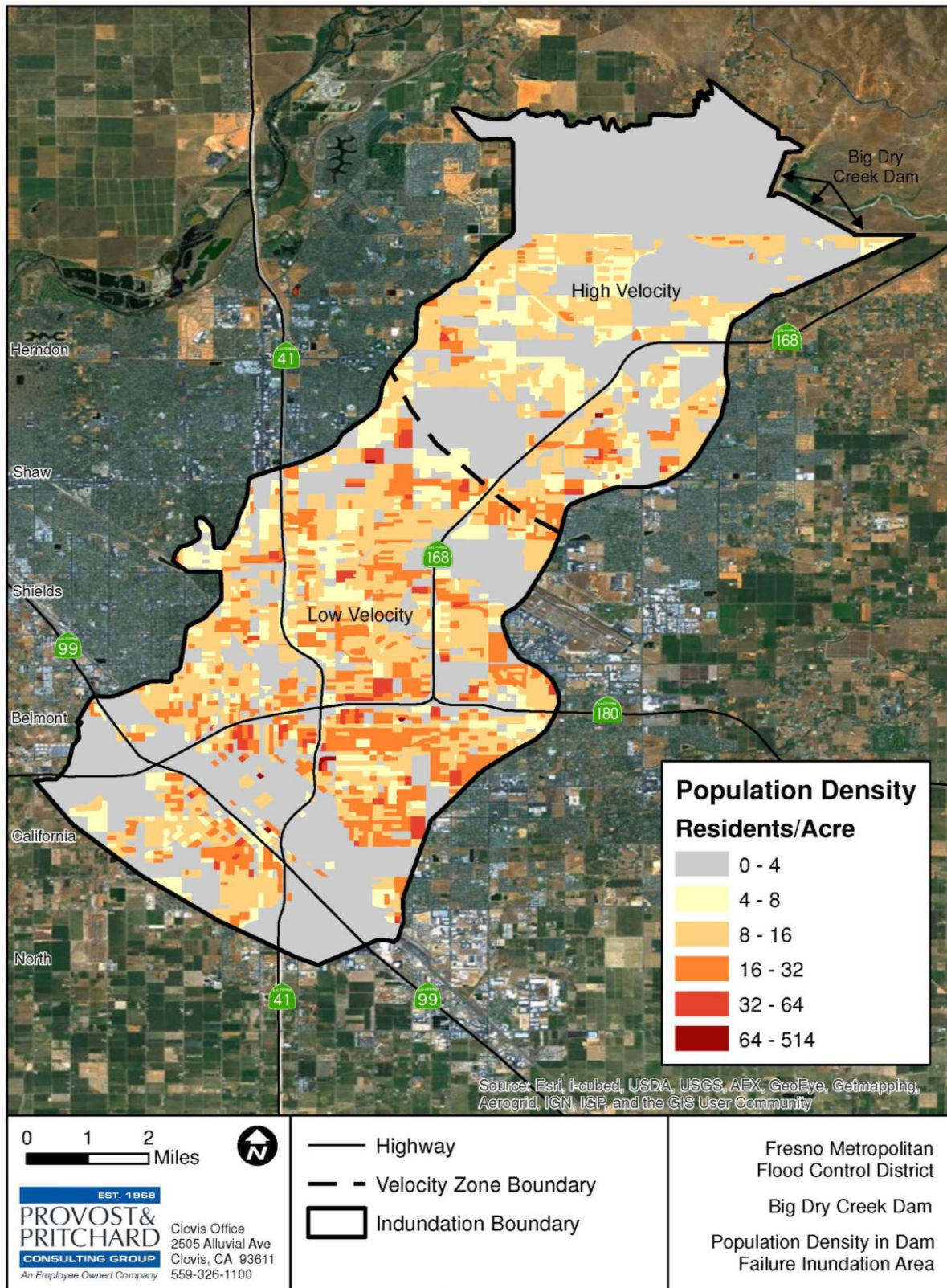


Figure 8.3 – Population Density in Dam Failure Inundation Area

Failure of flood management structures

Other flood management structures in the path of a dam failure include several canals used to convey irrigation water, stormwater runoff, and floodwater. The USACE determined that if the canals breached they would not significantly contribute to the overall flooding.

The expected annual damages are calculated in Table 11a (Appendix 8-2) and are estimated to be \$3.2 million. These include damages to residential homes, apartments and condominiums, commercial/industrial buildings, critical facilities and dam breach repairs (Table 11a). The present value of the damages is estimated to be \$50.0 million, as shown on Table 12a.

Non-Monetized Benefit Analysis

Following are discussions of non-monetized benefits. These benefits were not monetized primarily due to lack of data or an accepted methodology. The US Bureau of Reclamation (2009) also acknowledged that there are no reliable ways to estimate some of these impacts, such as emergency response costs.

Avoided loss of function

Specific functions that will be temporarily lost after a dam failure are listed below:

- Ability of impacted citizens to work
- Ability of businesses to operate or stay open
- Flood control benefits of the dam
- Recreational benefits (hiking, biking and picnicking) at the dam
- Ability to keep schools and daycares open
- Ability to transport goods or people due to flooded, damaged or silted roads

Avoided Emergency Response

Emergency costs include additional expenses resulting from a flood that would not otherwise be incurred, such as evacuation, reoccupation, temporary housing, flood fighting, disaster relief, and increased cost of police, fire or military patrol.

Avoided Public Safety and Health Impacts

Potential public safety and health impacts include the following:

- Looting and disorderly behavior in flooded areas
- Contaminated water supplies
- Disrupted sewage and garbage collection services
- Injuries from high flows and debris impact
- Damaged powerlines
- Long-term mold in flooded structures

The USACE addresses potential fatalities in the dam break study (USACE, 1996) as follows:

“Although flooding will be extensive within developed areas, modeled flood depths and velocities are generally non-life threatening to healthy adults”

Recent housing developments near the dam may increase the potential for fatalities. However, they were assumed to be zero in this analysis.

Agricultural losses

The inundated area includes patches of agricultural land covering 1,968 acres. Many of the crops are permanent plantings including oranges, peaches, almonds, pecans, apricots and nectarines. Some field crops are also planted in the area. Shallow flooding would probably have minimal damage to permanent plantings, unless they are immature. Field crops could be damaged from shallow flooding. Flooding could also damage irrigation equipment and erode topsoils. The damage would depend on the time of year flooding occurs and the current condition of crops. Due to these unknowns a monetary value was not assigned to agricultural losses.

Groundwater Recharge

The dam improvements will allow greater water retention at the end of the rainy season. This water can then be discharged slowly and distributed to stormwater basins for recharge. The volume of recharge is estimated to average 250 AF/year. However, the monetary value of the recharge is very small compared to the flood damage reduction benefits, so they were not considered.

Water Quality

The dam will facilitate the removal of an additional 37.5 tons/year of sediment from runoff since greater volumes can be stored behind the dam.

Uncertainty of Benefits

There is high certainty that the economic analysis is accurate. Several detailed studies were performed to assess the risks and impacts from a dam failure. These include studies by the US Army Corps of Engineers and BSK Associates. The analysis also uses low damage estimates based on flooding less than 6 inches deep in urban areas, when flooding is estimated to be 1 to 2 feet deep. The analysis only considers flood damage in the High Velocity Zone, and assumes that all residents in the Low Velocity Zone can eliminate flood damage through interventions (sand bagging, relocating, etc.). In reality, only a portion of the residents would have time or resources to prevent flood damages.

In addition, some benefits were not monetized, but could significantly improve the project benefit cost ratio if data were available. These non-monetized benefits included:

- Avoided loss of functions
- Avoided emergency response costs

- Avoided public safety and health impacts, and
- Agricultural losses.

Description of Adverse Effects

No significant adverse effects are expected from implementing the project. Some short term impacts, such as noise, dust, and traffic, will occur during construction of the toe drain. Preventative and mitigative measures will be taken to keep these impacts to a minimum and comply with local regulations.

Annual Benefits

The annual physical benefits are estimated to be \$3.2 million, as shown on Table 11a (Appendix 8-2).

Avoided Costs

Avoided costs are capital costs that could be eliminated by construction of the toe drain. The project will not have any avoided costs.

Proposed Costs and Benefits Summary

Table 17a (Appendix 8-2) shows the overall project costs and benefits for the Big Dry Creek Dam Toe Modification. The total present value of discounted costs is estimated to be \$3.1 million, which includes construction of the toe drain, replacement of a pump station and monitoring wells after 25 years, seepage pumping, and periodic seepage analysis reports. The total project benefits from flood damage reduction are estimated at \$50.0 million. This provides a benefit cost ratio of 16:1. This ratio is relatively high, but is realistic since it reflects the potential damage from a large dam failing upstream of a large metropolitan area.

References

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US Army Corps of Engineers – Sacramento District, *Water Control Manual, Big Dry Creek Reservoir and Diversion, Big Dry Creek, California, Appendix 12 to Master Water Control Manual San Joaquin River Basin, California*, October 1993.

US Army Corps of Engineers, *Dam Breach Analysis for Big Dry Creek Dam, California*, September 1995.

US Bureau of Reclamation, *Economic Consequences Methodology for Dam Failure Scenarios*, Technical Memorandum Number EC-2009-01, September 2009.

US Bureau of Reclamation, *Estimating Economic Consequences from Dam Failure in the Safety of Dams Program*, September 2000.

STORMWATER BASINS

Project Costs

The estimated cost for the three stormwater management basins is \$10.82 million. This includes costs for engineering, land acquisition, permitting, construction and construction management. A copy of a detailed cost estimate is provided in Appendix 8-6.

Operation and Maintenance Costs

Operation and maintenance costs for the stormwater management basins will include pumping costs, pump maintenance, and general basin maintenance. Pumping costs at the basins were estimated assuming that 600 AF, about half of the basin volumes, is pumped out on average each year. This is a reasonable assumption based on historical pumping at other FMFCD basins. The estimated pumping cost is \$10,200 each year, with salary expenses of \$600/year to monitor and control pumps. This results in total operation costs of \$10,800/year.

Pump maintenance costs are estimated to be \$500 per pump every year. FMFCD has data that shows the cost to maintain a developed basin (landscaped perimeter) is about \$2,300/acre/year, and the cost to maintain an undeveloped basin (no landscaping) is approximately \$150/acre/year. The three basins will include about 80 undeveloped acres and 4.6 landscaped acres and will have annual maintenance costs of \$22,580. Other tasks, including regular inspections and minor maintenance, will be performed by FMFCD staff as part of their regular duties, and will not incur additional costs.

Replacement Costs

Each basin will include a pump station that will likely require replacement after 25 years, so replacement costs of \$50,000 per pump, or \$150,000 total, will be incurred in year 25. The excavated basins and other facilities are estimated to have life expectancies of 50 years.

Present Value

The total value of the costs over a 50-year life cycle is shown on DWR Economic Table 16b (Appendix 8-7). The project has a total present value of discounted costs of \$11.4 million.

Identification of Flood Events and Flooding Locations

Location of Flood Control Benefits

FMFCD has an integrated flood control system including numerous reservoirs, stormwater basins and conveyance channels. These facilities are interconnected, and when a large storm occurs FMFCD can't prevent damages from the floodwater if the storm is in excess of a 25-year 96 hour storm. In storms greater than this, FMFCD will run out of storage capacity and channel flood routing capacity. Then FMFCD must store, divert and convey floodwater around the system as best it can to minimize damages throughout the entire district.

The three stormwater management basins proposed with this grant application will provide up to 1,227 AF of additional storage capacity at ultimate build-out (1,077 AF at end of grant, of which 20 AF is actually percolation). In addition to the storage capacity needed for local runoff that drains to the basins, the basins will also accommodate floodwater diverted directly from floodwater channels. The new stormwater basins will therefore allow FMFCD greater flexibility in managing floodwaters, and would be used to reduce flood damage in other areas of FMFCD considered the most susceptible to flooding.

Figure 8.4 shows a 22-square mile area that is highly susceptible to flooding in large storm events. This area includes 18 stormwater basins. These stormwater basins ultimately drain to local drainage areas WW, VV and DD, which are adjacent to the Herndon Canal. This is the area that will directly benefit from the three new stormwater basins, as described below.

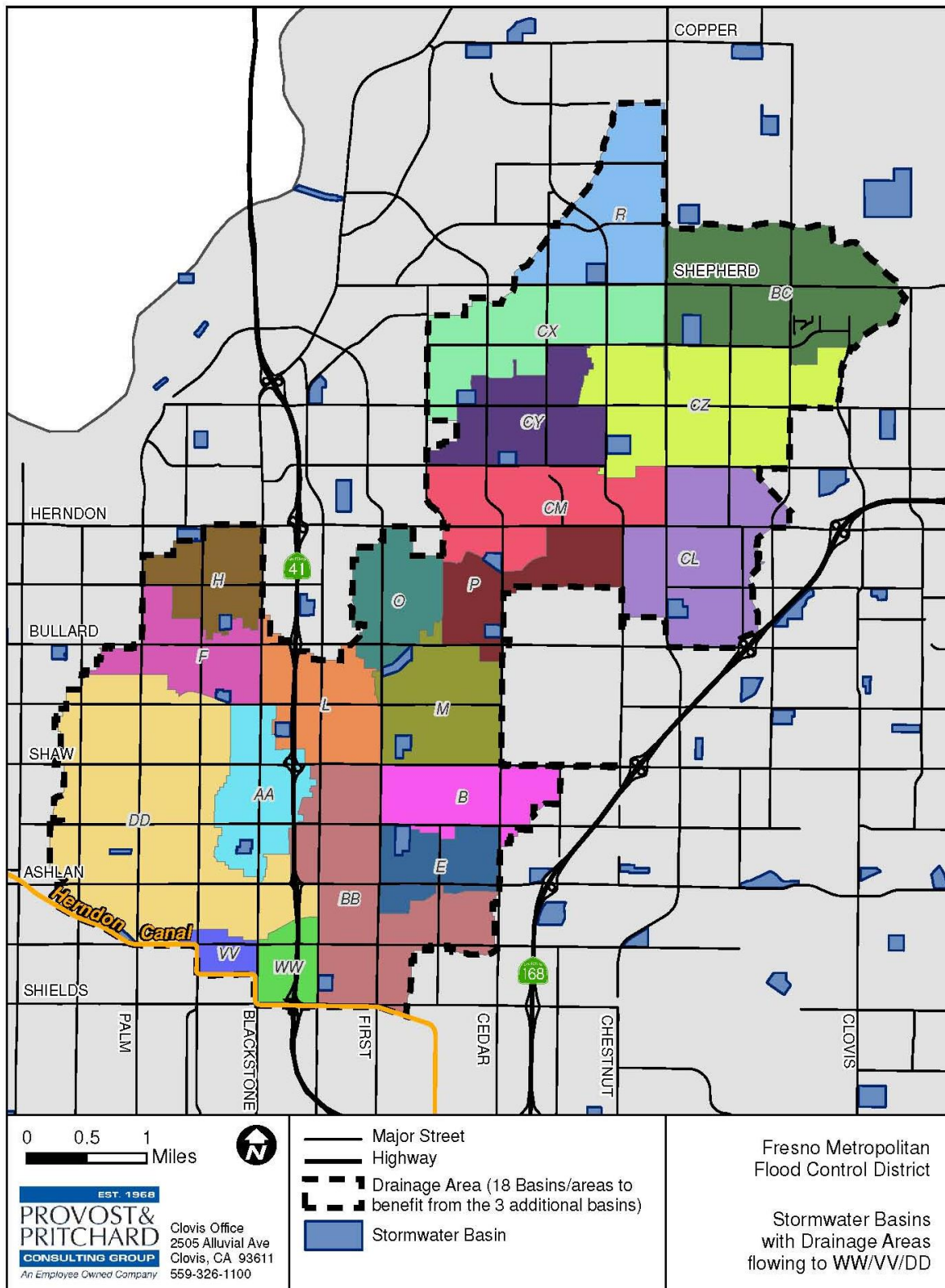


Figure 8.4 – Stormwater Basins with Drainage Areas Flowing to Herndon Canal

In this area the overflow runoff from 18 retention basins collects north of the Herndon Canal from Palm Avenue to Freeway 41. When surface flooding occurs the Herndon Canal impounds water increasing flooding in the local area. The greatest flooding occurs around local Drainage Areas WW, VV and DD, which abut the Herndon Canal. In a 200-year storm, these basins have the greatest flooding depth of the 18 basins (2.7 to 3.5 feet), with a combined flooded area exceeding 550 acres.

The stormwater management basins are relieved by pumping water from the local Drainage Areas into the local irrigation canal system. This system ultimately drains to the Herndon Canal, and represents about 33% of the pumping demand into the canal system. The Herndon Canal receives water from upstream and has limited capacity to handle the dewatering of the storm basins to make room for the more urban stormwater. Flooding will occur when the local runoff exceeds the storage capacity of local stormwater basins and the ability to pump runoff into the Herndon Canal.

The three new stormwater management basins can divert and store water from flood control channels that will allow the Herndon canal system to accommodate more storm flows from this area. The Pup Creek Enterprise Basin can reduce flows to the Big Dry Creek Channel and Big Dry Creek Detention Basin can divert water directly from the Big Dry Creek Canal. This canal turns into the Herndon Canal, so diversions from Big Dry Creek Canal into new stormwater basins will free up conveyance capacity in the Herndon Canal. The Dry Creek Extension Basin can capture and hold flows from the Dry Creek Canal which originates from Mill Canal. Mill Canal can flow either into Herndon Canal or to the Dry Creek Canal. The Dry Creek Extension Basin can therefore allow more Mill Canal water to bypass Herndon Canal, and free up conveyance capacity. As a result, the three proposed stormwater management basins can help to reduce flooding in this 22-square mile area by providing more conveyance capacity in the Herndon Canal where floodwaters can be pumped into. **Figure 8.5** is an overview map showing the three proposed basins, major flood control channels, area benefiting from the new basins, and locations of pumping facilities along the Herndon Canal and tributaries to the Herndon Canal.

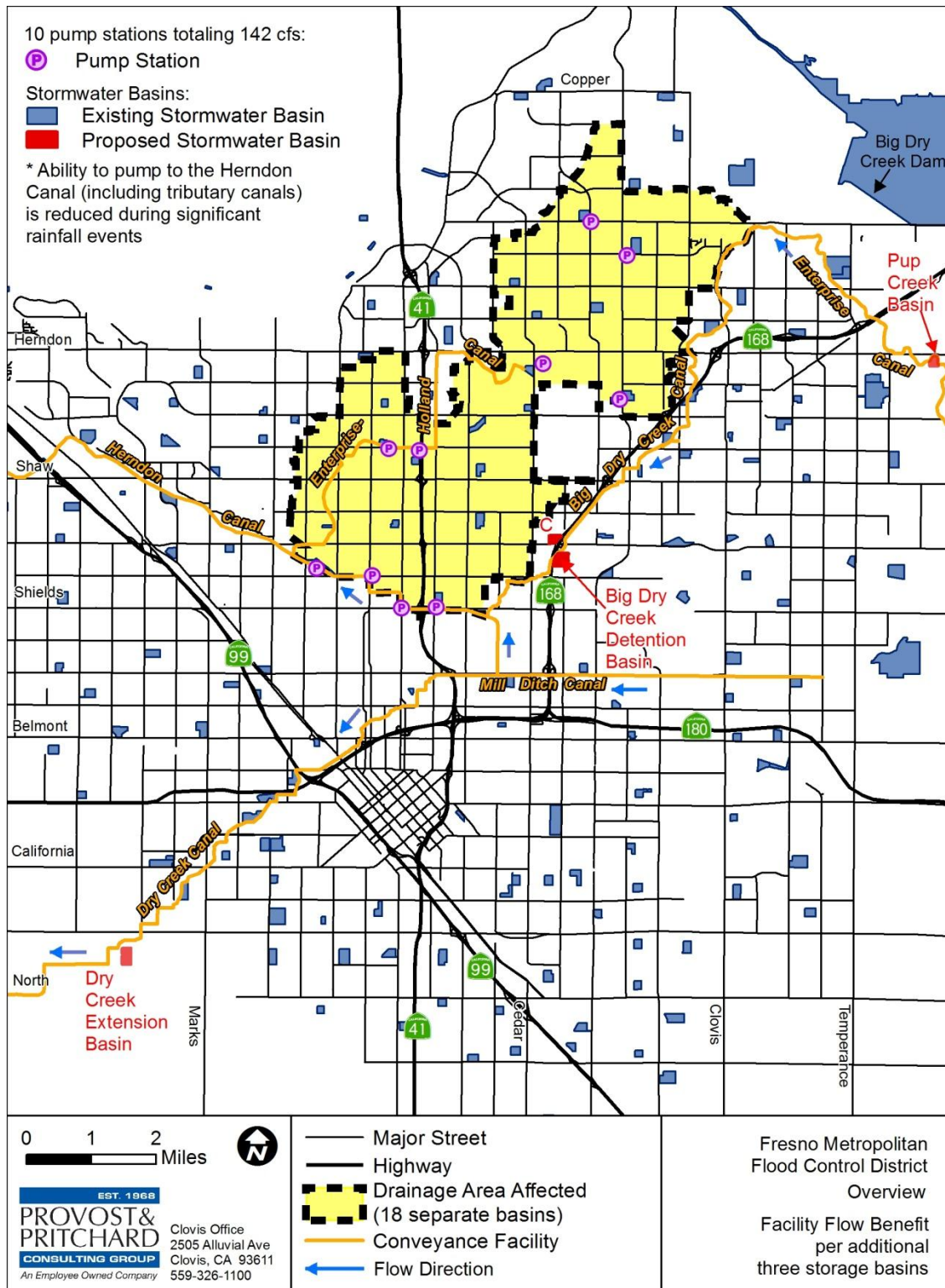


Figure 8.5 – Overview Map of Project Facilities

Selection of Flood Events

Modeling has shown that the urban pumping is most restricted in the 4th wave of a 30 day rainfall event. See Table 8.12. The current system of basins and on-demand pumps in the analyzed area can currently accommodate the 4th wave of a 30 day rainfall event at the 25 year return frequency. However, at higher frequencies flooding starts to occur. The flood events that were analyzed for the benefit-cost analysis include the 50-year, 100-year and 200-year storm.

Delineation of Flooded Areas

Flooding will occur when the local runoff exceeds the storage capacity of local stormwater basins and the ability to pump runoff into the Herndon Canal. The calculations for the volume of excess stormwater generated in the 22 square mile area is shown on Appendix 8-8. FMFCD performed modeling to determine the level of flooding by considering the total runoff, volume in stormwater basins, and volume that can be pumped into flood channels. The areas flooded were delineated using existing topographic data and assuming that floodwater accumulates in low-lying topographic areas. Topographic data used included top of curb grades, grading plans, pad elevations and topographic maps.

An important part of the study was to determine how much capacity is available in the Herndon canal, since less is available to the project area during larger storms. In these cases upstream rural flows are delivered to the canal and reduce the available conveyance capacity. FMFCD determined how long urban pumps would need to be turned off or reduced to allow rural flood water to be conveyed through the Herndon Canal. The usual pumping rate for the urban system has been established to be 350 cubic feet per second (cfs). The maximum flow the Herndon Canal can convey is 550 cfs. The Herndon Canal must convey releases from the Fancher Creek Detention Basin and other foothill flood water. This water has priority over the urban pumping (dewater the storm water detention basins) as the flow is uncontrolled. Any time these uncontrolled flows exceed 200 cfs, the urban pumping will need to be reduced to match the maximum flow in the Herndon Canal e.g., 250 cfs foothill flows plus 300 urban pumping equals 550 cfs (Herndon Canal maximum capacity) which is a 50 cfs reduction in urban pumping. As the foothill runoff increases the urban pumping will need to be reduced to a point of being turned off completely. The table below indicates the acre feet of water (on a per wave and total basis for the indicated storm return frequencies) that cannot be pumped from the urban basins due to the uncontrolled foothill flow.

Table 8.12 – Reduction in Urban Pumping to Flood Channels due to Rural Floodwater

	Wave Number						
	1	2	3	4	5	6	
Return Frequency	Acre Feet Reduction in Urban Pumping						Total AF
10		0.0	47.4	290.9	4.8	0.0	343
15	0.0	0.0	115.2	426.5	41.1	0.0	583
20	0.0	0.1	180.7	532.0	83.0	1.3	797
25	0.0	9.8	241.8	650.5	130.0	11.9	1,044
50	2.2	75.8	511.9	1,249.3	620.0	157.8	2,617
100	35.9	218.4	870.9	2,003.1	1,415.9	553.9	5,098
200	98.4	382.4	1,159.0	2,593.2	2,040.3	963.0	7,236

The flood routing scenarios are derived from utilizing a flood routing spreadsheet developed by Blair Church and Flynn Consulting Engineering for routing the 200 year, 96 hour, 30 day storm event flood flows from the Fancher Creek Detention Basin through the Herndon Canal. The spread sheet was modified to use the return frequency ratios developed by the U.S. Army Corps of Engineers for the Redbank and Fancher Creeks Project. Due to the voluminous nature of the spreadsheet is has not been included, but it is available upon request. The 200 year outflow from the Fancher Detention Basin and any foothill water entering the canal system downstream of the basin was ratioed to simulate the flow for the 10, 15, 20, 25, 50, 100, and 200 year storm events.

Flood Damage Reduction Benefit Analysis

With Project Conditions

With the project, the flooded areas will be completely eliminated during the 50-year storm (see **Figure 8.6**). Flooded areas will be reduced during 100- and 200-year event as shown on **Figures 8.7 and 8.8**.

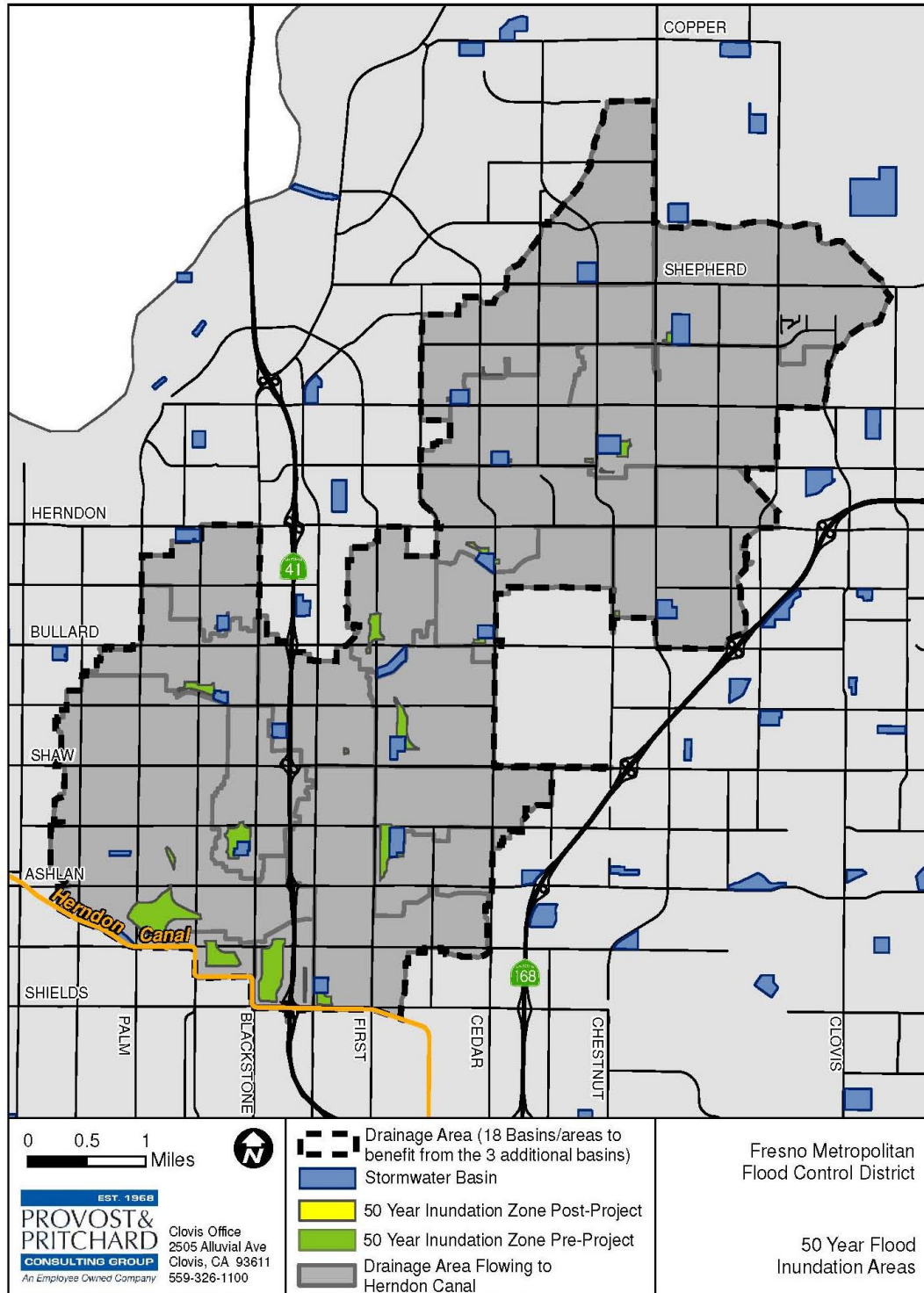


Figure 8.6 – 50-Year Storm Inundation Map

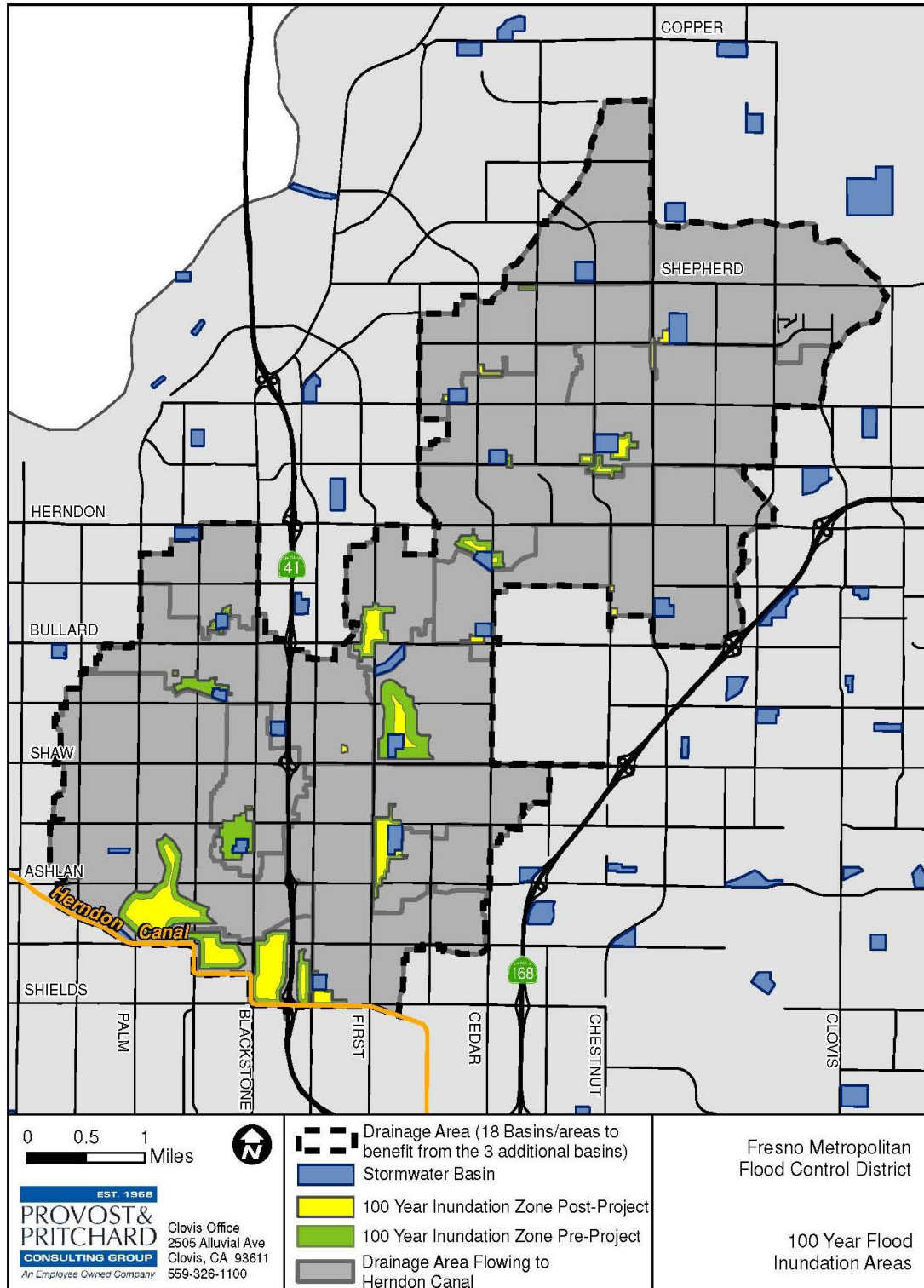


Figure 8.7 – 100-Year Storm Inundation Map

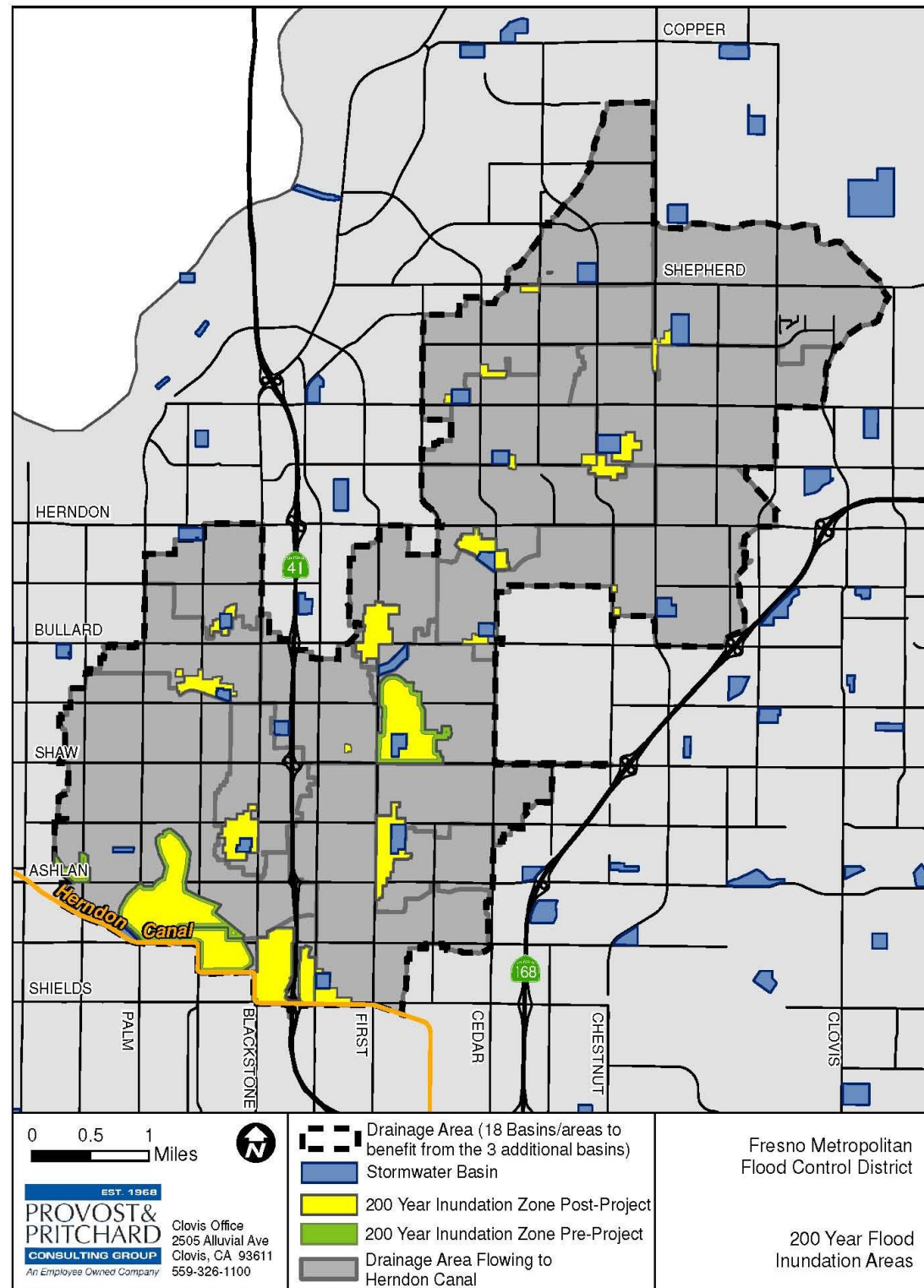


Figure 8.8 – 200-Year Storm Inundation Map

Without Project Conditions

Without the project, flooding will occur at existing levels during the 50-, 100- and 200-year storm, as shown on **Figures 8.6, 8.7 and 8.8**.

Avoided Physical Damage

The avoided physical damage will be the reduction in flooded areas after construction of the basins. Table 8.13 shows the areas of inundation with and without the project.

Table 8.13 – Flooded Areas With and Without Stormwater Basins (acres)

Return Interval	Pre-Project	Post Project	Difference
50-year	274	0	-274
100-year	802	343	-459
200-year	1,168	842	-326

Using aerial photographs, zoning maps and other geographical data, it was determined that most of the areas that would receive the flood reduction benefits are residential. Aerial photographs and parcel data show that typical housing densities in these areas area are at least 4 houses per acre, once roads, parking lots, parks and other vacant areas are considered.

Flood Depths

Table 8.14 shows the depth of flooding around each stormwater basin during the 50-, 100- and 200-year events determined by FMFCD when the inundation maps were prepared.

Table 8.14 – Flooding Depths in FMFCD Drainage Areas (ft)

Basin	50-Year Storm	100-Year Storm	200-Year Storm
B/E	0.43	0.82	1
M	1.03	1.97	2.4
P	0.43	0.82	1
R	0.21	0.41	0.5
BB	0.56	1.07	1
BC	0.51	0.98	1.1
CL	0.43	0.82	0.93
CM	0.56	1.07	1.3
CX	0.64	1.23	1.5
CY	0.51	0.98	1.2
CZ	0.51	0.98	1.2
F	0.43	0.82	0.93
H	0.26	0.49	0.57
L	0.30	0.57	0.67
O	0.77	1.48	1.85
AA	1.03	1.97	2.2
DD	1.50	2.87	3.5
VV	1.50	2.87	3.5
WW	1.20	2.30	2.7
Average	0.68	1.29	1.53

As shown on Table 8.5 in the section on Big Dry Creek Dam, flood damages vary with depth of water. Similar to the analysis for Big Dry Creek Dam, damages will conservatively be based on damage from only one inch of water, which was estimated at \$21,000/structure. Table 8.14 shows that actual flood depths will be about 0.5 to 1.5 feet.

Table 8.15 shows the reduction in flooded area, the estimated number of structures in each area, and the estimated damage to those structures.

Table 8.15 – Estimated Damage Reduction from Stormwater Basins

Return Interval	Reduction in Flooding (Acres)	Housing Density	Avg. Flooding Depth (ft)	Damage per Structure	Total Damage Reduction
50-year	274	4 houses/acre	0.7	\$21,000	\$23.0 million
100-year	459	4 houses/acre	1.3	\$21,000	\$38.6 million
200-year	326	4 houses/acre	1.5	\$21,000	\$27.4 million

Population Impacted

The population benefitting from the reduced flooding was estimated assuming 2.7 people per household and includes 2,960 people (50-year), 4,960 people (100-year) and 3,520 people (200-year).

Flood Response and Intervention

The analysis assumes that residents do not make any significant interventions to reduce flooding such as evacuation, relocating property, sandbagging, etc. Interventions such as sandbagging are uncommon and not part of the local culture, especially in urban areas located away from streams and rivers. The flooding will occur during a 96-hour event, and it is assumed that residents will not have sufficient time to plan and implement adequate response measures to prevent full damage from occurring.

The expected annual damages are calculated in Table 11b (Appendix 8-7) and are estimated to be \$1.03 million. The present value of the damages is estimated to be \$16.3 million, as shown on Table 12b.

Groundwater Recharge Benefits

As explained in Attachment 7, groundwater levels are declining in the Fresno-Clovis Metropolitan area. Consequently, new water supplies, including groundwater recharge, can provide a water supply and economic benefit. Each of the three proposed basins will capture and recharge stormwater that would otherwise leave the area.

The value of the recharged water is \$40/AF. This is the value of recharged groundwater reported by the City of Clovis and City of Fresno Water Division in January 2013. This value represents their cost to purchase Kings River water and operate groundwater recharge activities at similar basins.

The estimated recharge will increase gradually as the basins are expanded. The maximum recharge will be 1,990 AF/year at project completion. Refer to Table 14b (Appendix 8-7) for annual values each year and their associated benefit.

Non-Monetized Benefit Analysis

Following are discussions of non-monetized benefits. These benefits were not monetized primarily due to lack of data or an accepted methodology to quantify them.

Avoided loss of function

Specific functions that will be temporarily lost during flooding are listed below:

- Ability of impacted citizens to work
- Ability to keep schools and daycares open
- Ability to transport goods or people due to flooded, damaged or silted roads

Avoided Emergency Response

Emergency costs include additional expenses resulting from a flood that would not otherwise be incurred, such as evacuation, reoccupation, temporary housing, flood fighting, disaster relief, and increased cost of police, fire or military patrol.

Avoided Public Safety and Health Impacts

Potential public safety and health impacts include the following:

- Looting and disorderly behavior in flooded areas
- Contaminated water supplies
- Disrupted sewage and garbage collection services
- Damaged powerlines
- Long-term mold in flooded structures

Water Quality

Water quality improvements at the three stormwater basins will include:

- Improve water quality of up to 348 AF/year (after final build-out 498 AF/year)
- Remove 57.2 tons of sediment annually from stormwater (after final build-out 74.7 tons)

Public Education and Outreach

Public education and outreach at the Pup Creek Basin will include:

- Rest stop
- Shaded wildlife viewing pavilion
- Mounted binoculars
- Interpretive sign with information about wildlife in stormwater basins
- Estimated usage by at least 18,000 people/year

Habitat and Wildlife Improvements

Habitat and wildlife benefits at the three stormwater basins will include:

- Seasonal wetland and aquatic habitat inside secured fencing
- Water supply for wildlife
- Additional pooled surface area of 216 acres (after final build-out)
- Additional shoreline habitat of 4.5 miles (after final build-out)

Uncertainty of Benefits

There is high certainty that the economic analysis is accurate. The area that will benefit from the stormwater management basins, just north of Herndon Canal, has some of the greatest flooding risks in FMFCD, and will benefit from the new stormwater basins. The inundated areas were delineated using several sources of topographic data and are considered accurate. The estimate also uses conservative damage estimates that are based on 1 inch of flooding, when flooding will actually be between about 0.5 to 1.5 feet. In addition, some benefits were not monetized due to lack of data, but could significantly improve the benefit cost ratio if data were available.

Description of Adverse Effects

No significant adverse effects are expected from implementing the project. Some short-term impacts, such as noise, dust, and traffic, will occur during construction of the stormwater basins. Preventative and mitigative measures will be taken to keep these impacts to a minimum and comply with local regulations.

Annual Benefits

The annual physical benefits are estimated to be \$1.03 million, as shown on Table 11b.

Avoided Costs

Avoided costs are capital costs that could be eliminated by construction of the stormwater basins. The project will not have any avoided costs.

Proposed Costs and Benefits Summary

Table 17b (Appendix 8-7) shows the overall project costs and benefits for the three stormwater basins. The total present value of discounted costs is estimated to be \$11.4 million, which includes construction of the three stormwater basins, replacement of pump stations after 25 years, seepage pumping, and annual maintenance. The total project benefits from flood damage reduction and groundwater recharge are estimated at \$17.4 million. This provides a benefit cost ratio of 1.5 for the three stormwater basins.

OVERALL BENEFIT COST RATIO

The Big Dry Creek Dam Toe Drain and three new stormwater basins are considered part of the same project. These two components are integrated and provide the same benefits (i.e. increased floodwater storage) for the Fresno-Clovis Metropolitan Area. Below is a summary of total project costs and benefits:

Table 8.16 – Total Project Costs and Benefits

Project	Total Present Value of Project Costs	Total Present Value of Project Benefits
Big Dry Creek Dam	\$3.1 million	\$50.0 million
Three Stormwater Basins	\$11.4 million	\$17.4 million
Total	\$14.5 million	\$67.4 million

This provides an overall benefit cost ratio of **4.7**.